Forces and Motion
PS-5 The student will demonstrate an understanding of the nature of forces and motion.

PS-5.6 Represent the linear motion of objects on distance-time graphs.
Taxonomy Level: 2.1-B Understand Conceptual Knowledge

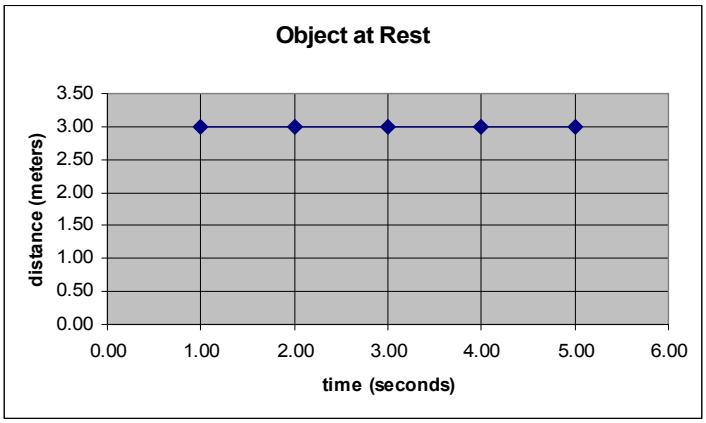
Key Concepts:
Distance/time graphs
Displacement/time graphs
Linear motion
Story graph

Previous/Future knowledge: In 5th grade students, use a graph to illustrate the motion of an object (5-5.5). In 8th grade, students use measurement and time-distance graphs to represent the motion of an object in terms of its position, direction, or speed (8-5.1). In Physical Science, students will again focus only on graphs of distance vs. time, but the focus here will be for students to understand and compare the shape of distance-time graphs for a variety of different types of motion.

It is essential for students to
- Construct distance/time graphs from data showing the distance traveled over time for selected types of motion (rest, constant velocity, acceleration).
- Compare the shape of these three types of graphs and recognize the type of motion from the shape of the graph.
- Discuss in words the significance of the shapes of the graphs in terms of the motion of the objects.

(1) ***An object at rest***
Example:

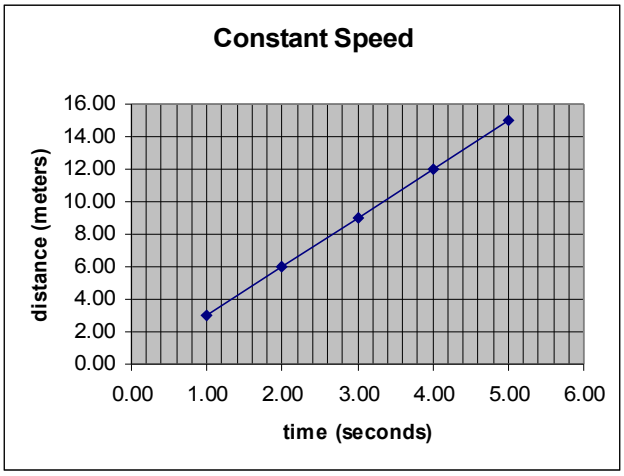
Elapsed Time (s)	Total Distance Traveled (meters)
1.00	3.00
2.00	3.00
3.00	3.00
4.00	3.00
5.00	3.00



The shape of the graph is flat, because between the 1st and 6th second there is no change in distance.

(2) ***An object with constant speed***
Example:

Elapsed Time (s)	Total Distance Traveled (meters)
1.00	3.00
2.00	6.00
3.00	9.00
4.00	12.00
5.00	15.00

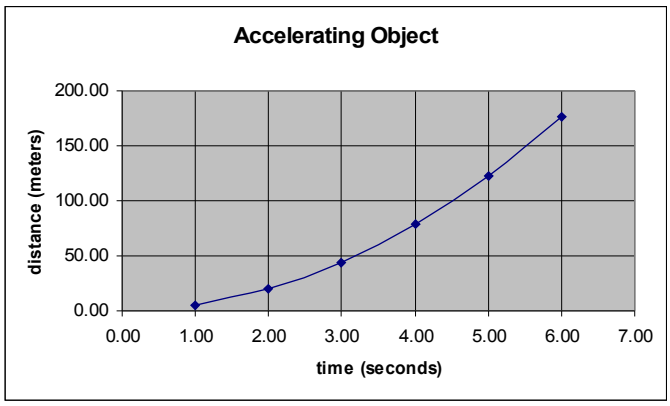


The shape of the graph is a diagonal straight line. The object covers the same amount of distance in each time period. As the time increases, the distance increases at a constant rate.

(3a) ***An accelerating object*** (positive acceleration or speeding up)

Example:

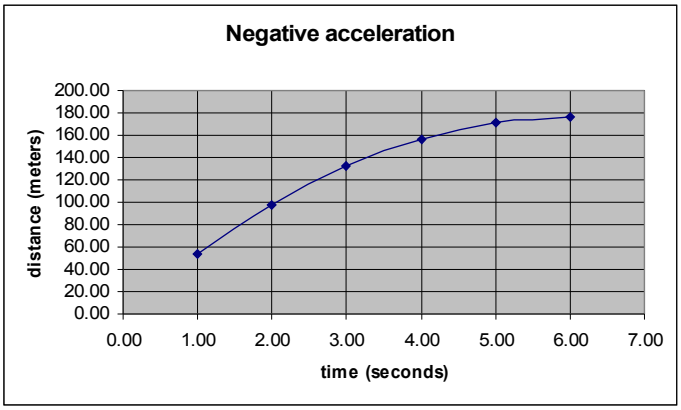
Elapsed Time (s)	Total Distance Traveled (meters)
1.00	4.90
2.00	19.60
3.00	44.10
4.00	78.40
5.00	122.50
6.00	176.40



The shape of the graph is a curve getting steeper because as time goes by, the object covers more distance each second than it did in the previous second so the amount that the graph goes up each second gets more and more.

(3b) ***A negatively accelerating object*** (an object slowing down)
Example:

Elapsed Time (s)	Total Distance Traveled (meters)
1.00	53.90
2.00	98.00
3.00	132.80
4.00	156.80
5.00	171.50
6.00	176.40



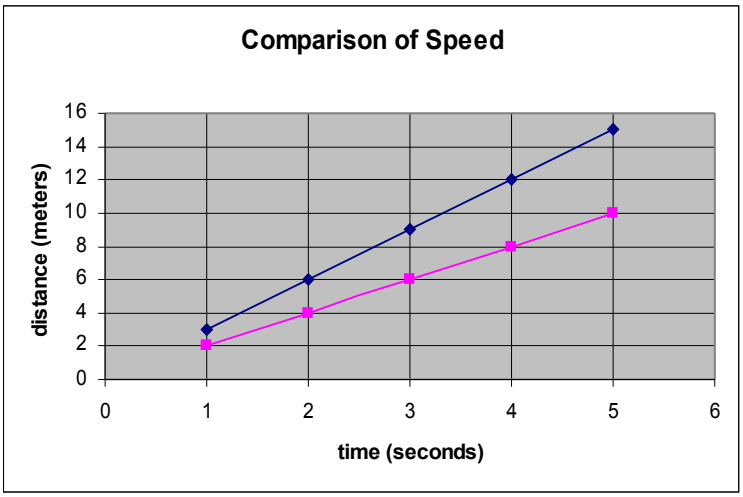
The shape of the graph is a curve getting flatter because as time goes by, the object covers less distance each second than it did in the previous second, so the amount that the graph goes up each second gets less and less.

It is essential for students to

- **C**onstruct distance time graphs from data that <u>compare</u> the motion of objects.
- Discuss the significance of the shapes of the graphs in terms of the relative motion of the objects.

(1) ***A comparison of two objects traveling at different speeds***
Example:

Elapsed Time (s)	Total Distance Traveled (meters) Object 1	Total Distance Traveled (meters) Object 2
1.00	3.00	2.00
2.00	6.00	4.00
3.00	9.00	6.00
4.00	12.00	8.00
5.00	15.00	10.00

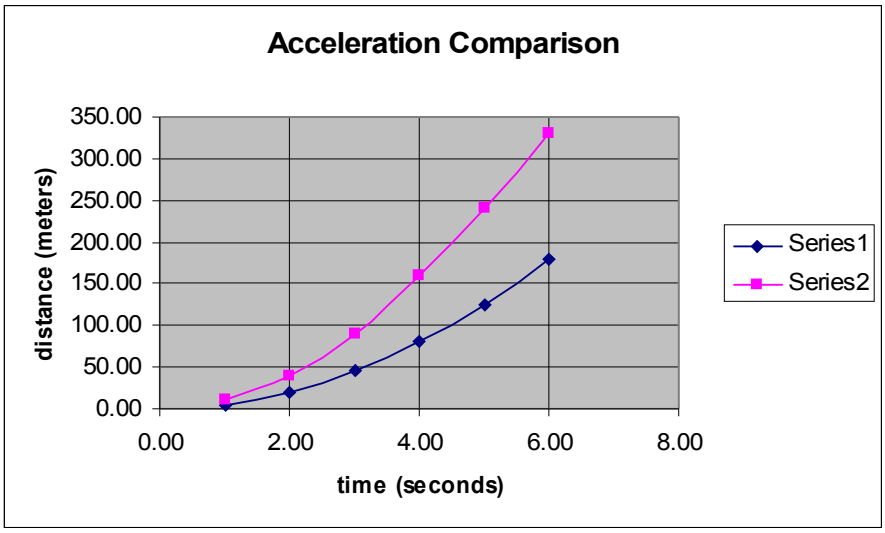


Both objects are traveling at a constant speed, but the object represented by the top line is traveling faster than the lower one. You can tell this because the amount that the graph goes up each second (which represents the amount of distance traveled) is more for the top line than for the bottom one. (The top line has a greater slope.)

(2) ***A comparison of two objects accelerating at different rates***

Example:

Total elapsed Time (seconds)	Total distance traveled (meters) Object 1	Total distance traveled (meters) Object 2
1.00 s	5.00 m	10.00 m
2.00 s	20.00 m	40.00 m
3.00 s	45.00 m	90.00 m
4.00 s	80.00 m	160.00 m
5.00 s	125.00 m	240.00 m
6.00 s	180.00 m	330.00 m



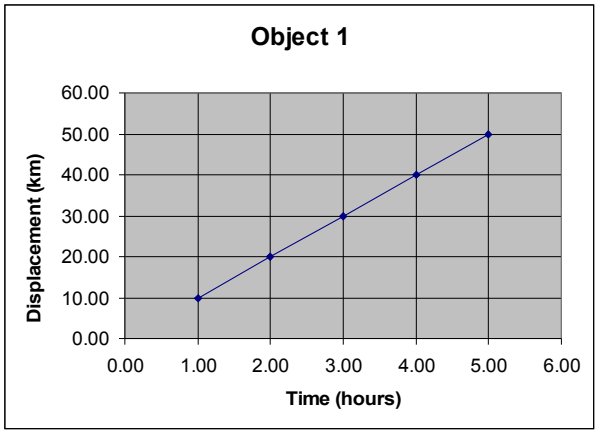
Both of the objects are accelerating, but the Series 2 object (top curve) is accelerating at a greater rate than the Series 1 object (bottom curve). Both objects cover more distance each second than they did during the previous second, but the amount of increase for series 2 is more than the amount of increase for (series 1).

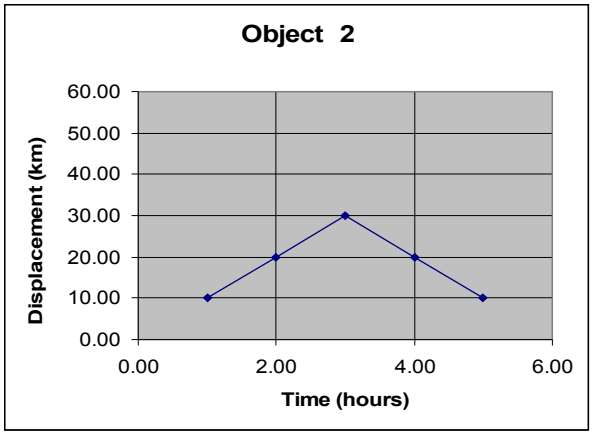
(3) ***A comparison of two objects traveling in different directions at a constant speed***
(to show this, a displacement-time graph is required)

Example:

Elapsed Time (s)	**Total Displacement (kilometers) Object 1**	**Total Displacement (kilometers) Object 2**
1.00	10.00 km West	10.00 km West
2.00	20.00 km West	20.00 km West
3.00	30.00 km West	30.00 km West
4.00	40.00 km West	20.00 km West
5.00	50.00 km West	10.00 km West

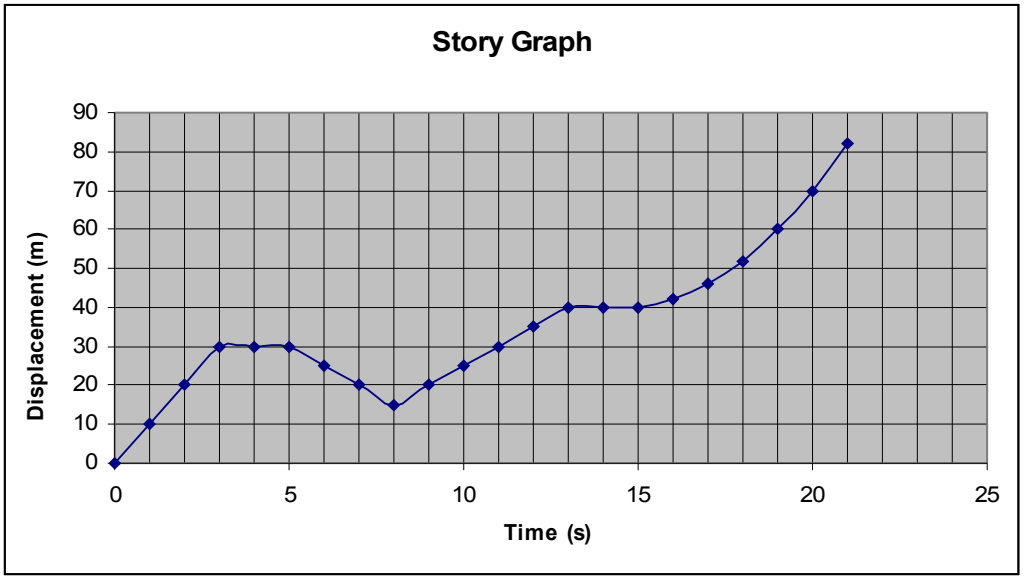
Direction Comparison





These are displacement-time graphs (displacement/location has distance and direction), so it shows how far each object is from the starting point after each hour. **Object 1** gets farther and farther away. At the 3rd hour, **object 2** turns around and comes back toward the start. The speed of each object is the same.

It is essential for a student to infer a possible story given a graph similar to this example.



Possible explanation.

- From 0 to 3 seconds the object is traveling at a **constant velocity away** from the starting point.
- From 3 seconds to 5 seconds the object is **not moving** relative to the starting point.
- From 5 seconds to 8 seconds the object is **moving at a constant velocity toward** the starting point.
- From 8 seconds to 13 seconds the object is moving at a **constant velocity away** from the starting point, at a velocity slower than the motion from 0 to 3 seconds.
- From 13 to 15 seconds the object is **not moving** relative to the starting point.
- From 15 to 21 seconds the object is **accelerating** (speeding up) as it moves **away** from the starting point.

It is not essential for students to

- Construct or analyze velocity-time or acceleration-time graphs;
- Determine velocity by mathematically calculating the slope of the graphs. Students should be able to interpret the meaning of the "steepness" of a graph;
- Graph any types of velocity graphs other than those which have been addressed such as velocity vs. time graphs.

Assessment Guidelines:

The objective of this indicator is to *represent* linear motion of an object on distance-time graphs, therefore, the primary focus of assessment should be to represent distance/time or displacement/time data in graph form or interpret distance/time or displacement/time graphs. The type of motion is restricted to rest, constant velocity, or constant acceleration. Students should apply their knowledge of graphical analysis of motion to any new set of data, verbal description, or graphical representation.

In addition to *represent*, assessments may require that students:

- *Exemplify* by finding a specific example of a type of graph which is appropriate for a given data set or verbal description of motion;
- *Classify* the type of motion (rest, constant speed, or acceleration) by the shape of a distance time graph;
- *Summarize* the shapes of graphs which represent specific types of motion;
- *Compare* the motion of two objects from graphical representations of their motion;
- *Interpret* distance/time and displacement/time graphs.